National Aeronautics and Space Administration

Extrasolar Kuiper Belts Imaged with the Spitzer Space Telescope

K.R. Stapelfeldt & G.C. Bryden (3262), M.W. Werner (7000), K.Y.L. Su & G. Rieke (U of Arizona), D.E. Backman (SOFIA/USRA), C.A. Beichman & A.M. Tanner (MSC/Caltech)

Project Objective

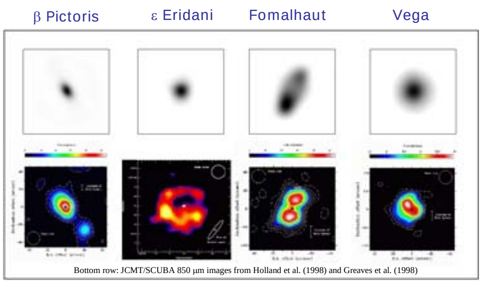
Almost 20% of main sequence stars have far-infrared excess emission from circumstellar dust. In about a dozen nearby stars, Spitzer/MIPS is able to spatially resolve these dust clouds and thus directly measure the size & structure of extrasolar Kuiper Belts. Through these studies, we seek a better understanding of our solar system in the context of those around stars of different masses and ages.

Project Description

- This is an observational project with the Spitzer Space Telescope. Two samples of nearby stars were targeted:
  1. Stars with infrared excess identified by the 1984 IRAS survey, and whose dust disks Spitzer should be able to spatially resolve with its 70 μm beamsize of 16″.
  2. Solar-type stars in a discovery survey, and which were serendipitously found to have spatially extended disks.
- Surprisingly, only 6/17 stars in the first group were found to have extended disks. This group is dominated by higher-luminosity A-type stars whose strong radiation pressure forces should quickly expel the small dust grains that most easily produce extended 70 μm emission. Alternatively, the disks of these stars could simply have small intrinsic disk diameters.
- Out of nearly 200 stars surveyed in the second group, at least 9 show extended disks. These lower-luminosity stars can retain smaller dust grains in their exo-Kuiper Belts, rendering them more detectable to Spitzer.

The Fabulous Four Debris Disks

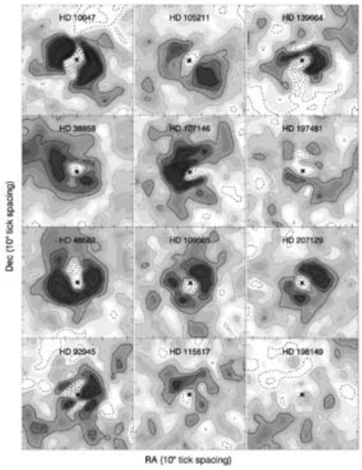
These four stars show the most extended disks in 70 μm images (top row). The distribution of far-IR emission is generally much smoother than the submillimeter emission seen by ground-based telescopes (bottom row). Fomalhaut's disk appears as a edge-on eccentric ring, 260 AU in diameter, with the periapse side appearing warmer. Vega's face-on disk is surprisingly large, with dust emission detected to distances of more than 1000 AU; these are small particles blowing out from the system by radiation pressure, indicative of a recent major asteroid collision.

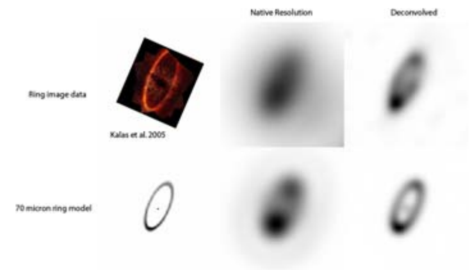


Bottom row: JCMT/SCUBA 850 μm images from Holland et al. (1998) and Greaves et al. (1998)

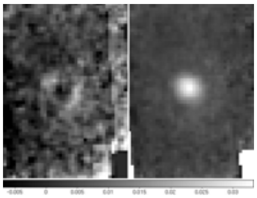
Other Resolved Dust Disks

Below: Solar-type stars found to have resolved disks at 70 μm. In each case, the faint extended emission is revealed after subtracting out the bright image core using the image of an unresolved reference star. Five of these disks are also resolved In scattered light by the Hubble Space Telescope, and found to be extended with the same size and position angle on the sky (see poster by Krist et al.) The others are too tenuous for detection with HST. These disks range from 100-200 AU in diameter (1-2 x our solar system's Kuiper Belt), but with dust inventories hundreds of times larger than our KB.



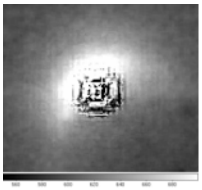


Above: Modeling the Spitzer/MIPS 70 μm image of Fomalhaut. The elliptical ring geometry determined from HST images by Kalas et al. (2005) was used. The model dust emission image (lower left panel) is shown convolved with a Spitzer/MIPS 70 μm point spread function (lower center); at lower right, the model is shown convolved with a Gaussian representation of the point spread function achieved by deconvolution with the JPL HIRES tool. These should be compared to the corresponding Spitzer images at top center and top right.



Above: MIPS 70 μm image of γ Ophiuchi, with and without PSF subtraction. An extended disk almost 1000 AU in diameter is seen at an intermediate inclination.

Below: δ Velorum. IRAS data indicated this star possessed a debris disk, but Spitzer finds that the IR excess actually arises from an interstellar bowshock. MIPS 24 μm image from Gaspar et al. (2008).



Benefits to NASA and JPL

Our results provide a direct exploration of the structure of nearby planetary systems. Through radiative and dynamical modeling, we are progressing toward an understanding of dust particle sizes; their sources, sinks, and transport mechanisms; and perturbations to the disk structure from unseen planets. Our results illuminate the nature of dusty backgrounds against which the future TPF and Darwin missions must contend as they seek to image and spectrally characterize exoplanets.

Publications

First Look at the Fomalhaut Debris Disk with the Spitzer Space Telescope, K.R. Stapelfeldt et al. (2004) Ap.J.S. 154 448
The Vega Debris Disk: A Surprise from Spitzer, K.Y.L. Su et al. (2005) Ap.J. 628 487
Modeling the IR Bowshock of δ Velorum: Implications for Studies of Debris Disks and λ Bootis stars, A. Gaspar et al. (2008) Ao.J 672 974
Five other papers by Backman, Bryden, Su, and Stapelfeldt are in various stages of preparation